Chapter 11
Unwatering and Drainage System

11-1. General

The unwatering and drainage system provides the means for unwatering main unit turbines and their associated water passages for inspection and maintenance purposes, as well as the collection and disposal of all powerhouse leakage and wastewater other than sanitary. The provisions for equalizing (filling) are closely related to unwatering and are included in this chapter. The safety of personnel and plant is of vital concern in this system and should have continuing priority throughout the design.

11-2. Unwatering System

a. General. The principal volumes to be unwatered in all powerhouses are the spiral case and draft tube. In addition, there is usually a considerable volume downstream of the headgates or the penstock valve. Some projects include extensive fish passage facilities with large volumes of water in pumps, channels, and conduits to be unwatered.

b. Detail requirements.

(1) Unwatering procedure. Normal procedure after unit shutdown requires the following: closing of the headgates or penstock valve; drainage of all unit water above tailwater to tailwater elevation through the wicket gates, and spiral case or spiral case extension drain; placement of draft tube bulkheads or stoplogs; and draining the remaining unit water to sump with the sump pumps operating.

(2) Unwatering time. Aside from safety, the required elapsed time for completing a unit unwatering is the major factor in unwatering system design. Unit downtime will usually be of a value justifying facilities to accomplish unwatering in 4 hr or less. This can mean that in a typical plant all necessary valve, gate, and stoplog or bulkhead operations should be done in approximately 1 hr and draining of the pumping system in approximately 3 hr. Such a schedule has been attainable and justifiable on existing projects.

(3) Spiral case drains. Spiral case drains should normally be sized to preclude draining of the spiral cases from becoming a controlling factor in total unwatering time. Oversizing to the point where misoperation could result in excessive unseating head and damage to draft tube stoplogs or tailrace structure must be avoided, particularly in plants where opening the drain valve is part of the equalizing procedure. It will usually be found that with properly sized drains the unseating force on the draft tube stoplogs will result in enough leakage to prevent a damaging pressure rise. The drains should normally be provided with manually operated rising stem-gate valves for control. However, portable or fixed power operators can be justified on the larger sizes. Maximum flow velocities will usually render butterfly valves unsuitable. The designer should be aware of the flooding hazard resulting from a failure in this line and provide a layout with conservatively rated components and in which alignment and necessary flexibility can be reasonably attained. Typical sizes in existing plants are in the 100-200-mm (4-8-in.) range for small Francis unit plants and in the 400-500-mm (16-20-in.) range for large Kaplan unit plants. Spiral case drains should discharge to the draft tube to preclude pool head on the unwatering sump. A connection for introducing station compressed air immediately upstream from the control valve to dislodge packed silt and debris is normally required.

(4) Draft tube drains.

(a) Draft tube drains should be sized with consideration for leakage from the following: intake gates, intake valves, and structural relief drains; draft tube bulkheads or stoplogs; the required unwatering time; and the assurance of seating the draft tube bulkhead or stoplogs. With average design and workmanship on bulkheads, stoplogs, and guides, the 3-hr draining requirement usually will result in a large enough draft tube drain to seat the bulkhead or stoplogs. A short drain line discharging into a large conduit and sump results in a high initial flow rate ideal for the seating requirement. Where drains are manifolded directly into the pump intakes, the individual draft tube drains tend to be smaller, and the maximum capacity of the entire system should be evaluated for the possibility of unseated leakage, plus other leakage, which equals or exceeds the drainage capacity.

(b) Valves for the draft tube drains are usually either a submerged rising plug type (mud valve) or standard in-line rising stem-gate valves. The rising plug type offers a drain line installation not subject to plugging from packed silt and no exposed components subject to flooding hazard failures. Its disadvantage is the head requirements, for large units with deep submergence are usually not within standard valve ratings which result in nonstandard equipment. Attempts to upgrade standard valves usually causes problems in obtaining valves with adequate safety factors for all hydraulic forces and operator forces. Standard gate valves and operators are available as off-the-shelf items for installations in a dry pit location accessible to the embedded drain line, but the potential for line plugging between the draft tube and valve is disadvantageous. Short lines with compressed air blowout connections will minimize unplugging problems. This type of valve installation is ordinarily restricted to smaller plants without an unwatering header or tunnel. For the larger units with deep submergence, the preferred valve is either a standard design gate valve suitable for submergence in a draft tube recess or special design plug-type valve with design for the required head completely detailed in the contract drawings. Stainless steel water-type knife-edge gate valves suitable for submerged extended stem operation have been used at several recent projects and are expected to give reliable service. Two valves should be installed in draft tube locations to provide unwatering capability with one valve inoperable, but required unwatering time should be on the assumption that both valves are operable. Powered operators, either portable or fixed, are usually justified for the larger installations. Butterfly valves are generally unsuitable because of high velocities.

(c) Draft tube drains may be run individually to the unwatering sump in small plants but are usually discharged into a large pipe header or formed conduit leading to the sump in large plants. The formed conduit has definite advantages in large Kaplan unit plants as it can be large enough for inspection and cleanout, can form an effective addition to sump capacity, and is often more economical than a pipe header.

(d) The flooding hazard precautions noted in 11-2*b*(3) are also applicable to draft tube drains.

(5) Unwatering sumps.

(a) Sump provisions in most projects require either joint usage in both the unwatering and drainage systems, or separate sumps with the unwatering sump serving as a backup or overflow for the drainage sump. Size and configuration specifications require close coordination with the planned pumping provisions and inflows to permit practical pump cycles with adequate backup and effective high-level warning provisions. Whenever space and reasonable cost permit, it is preferable to provide oversized sumps to allow more flexibility to accommodate unexpected leakage, additional or larger pumps, or revised operating procedures.

(b) Sumps should be designed for maximum tailwater head with assumed pump failure and be vented above maximum tailwater.

(c) Floors should be graded to a small sump within a sump to permit use of a portable pump for maintenance unwatering the main sump.

(d) With separate sumps, the drainage sump overflow should be above the lag pump “on” elevation and be provided with a check valve which has a pressure rating based on maximum tailwater.

(6) Unwatering pumps. The unwatering and drainage pumping provisions require, along with the sumps, consideration of their individual and joint usage requirements. Usually, more than one combination of pumps will be practical for any application. However, the following general principles should be observed:

(a) Sump configuration and automatic start-stop settings should allow a minimum of 3-min running time per cycle for all pump selections.

(b) Pumps should be suitable for operation at zero static head.

(c) Pumps should have continuously raising performance curves.

(d) Pump motors and controls should be located above average peak flow tailwater.

(e) Silent-type check valves should be used in pump discharge lines.

(f) Where space is available, the preferred provisions should include the following: separate unwatering and drainage sumps, separate unwatering and drainage pumping provisions, and automatic overflow from the drainage sump to unwatering sump.

(g) With separate systems, unwatering pump capacity should permit unwatering in 3 hr or less of pumping time with total capacity divided in two pumps of the same capacity. Either pump used alone should be capable of accomplishing an unwatering. Since unit unwatering will not be scheduled under powerhouse design flood conditions, rated unwatering pump discharge should be for a maximum planned tailwater under which unwatering will occur. To provide backup for the drainage system, the unwatering pumps should have a reasonable capacity at powerhouse design flood conditions.

(h) With separate systems, the drainage pump capacity should be divided between two pumps of the same capacity. Each should be capable of pumping a minimum of 150 percent of maximum estimated station drainage at an average peak-flow tailwater and with combined capacity to handle estimated station drainage at powerhouse design flood.

(i) With combined single-sump systems, the drainage-unwatering two-pump capacity should meet the stated minimum requirements for separate systems. The two pumps should pump from an in-sump manifold with valved connections from unwatering lines and a valved inlet from the sump. The manifold inlet valves should be manual, and design should be based on station drainage accumulating in the sump during an unwatering operation. A third manually controlled pump of the same capacity should be installed as backup for the drainage function. Suction for the third pump should be directly out of the sump, not through the header.

(j) Pumps of the deep well water-lubricated type will usually be preferred. Water jet educators can seldom be justified from an efficiency standpoint, and dry pit pump installations are less desirable in safety and cost considerations. Submersible motor and pump combination units mounted on guide rails permitting the pump units to be raised or lowered by the powerhouse crane have been used on several recent jobs. Provisions are included for automatic connection to the pump discharge line. This design eliminates the long pump shafts and simplifies maintenance.

(k) Either pneumatic bubbler-type or float-type controls are satisfactory for pump control. A separate float type of control should be provided for the drainage sump (or combined drainage-unwatering sump) for high-water alarm. Automatic lead-lag with manual selection of the lead pump is preferred.

(l) Whenever practicable, minimum piping (particularly embedded), sump capacity, and pump arrangement backup provisions should permit the addition of future pumping capacity.

(7) Discharge piping. Unwatering system discharge lines normally terminate above the average peak-flow tailwater. Therefore, reliance is on the discharge check valves for prevention of backflow at high tailwaters and permission of line and check valve maintenance at lower tailwaters. Individual pump discharges to the tailrace are preferable, but a single discharge header for combined unwatering-drainage pumps and a single header each for separate unwatering and drainage systems will usually be found more practicable to use.

(8) System diagrams. Figure B-10 shows typical unwatering-drainage systems.

c. Miscellaneous.

(1) Unwatering of nonpowerhouse facilities. It is acceptable to utilize the unwatering conduit, sump, and pumps for unwatering of fishway conduits, channels, and pumps as well as other facilities in or adjoining the powerhouse. However, frequency of use, length of lines, line plugging, safety, required unwatering time, cost, and possibility of conflicting unwatering schedules should be carefully evaluated. Portable equipment is frequently a preferable choice.

(2) Construction usage. Use of the unwatering facilities for construction requirements or for maintaining skeleton (future) powerhouse bays in an unwatered condition should not be planned. Questionable condition of equipment and fouling of lines with construction debris after such usage will be usually experienced.

11-3. Drainage System

a. General. The drainage system handles three general types of drainage as follows: rain and snow water from roofs and decks, leakage through structural cracks and contraction joints, and wastewater from equipment. Discharge is to tailwater either by gravity or by pumping from a drainage sump.

b. Roof and deck drainage. Roof and deck drainage should normally be directly to tailwater by gravity. However, where the powerhouse forms a portion of the dam structure, it may be feasible to drain the intake deck to pool. A minimum of two roof drains per bay should be provided to minimize flooding from plugging. Deck drains should be located to eliminate standing water and should consist of short vertical runs of piping wherever practicable in freezing areas. Decks with open block-out type of rail installations should be provided with block-out drains. Size of roof and deck drains should be based on the greater of applicable code requirements or maximum 1-hr rainfall figures for the area. Deluge system flows should be added where applicable.

c. Floor drainage.

(1) Drainage galleries. Drainage galleries and other galleries with a wall in contact with water or a fill below high tailwater should be provided with a drainage trench. The trench should be sized and graded for maximum estimated leakage based on existing similar powerhouses. Unless located in grouting galleries, trenches should not cross contraction joints without provision of water stops. Conduits connecting the trenches to the drainage sump and the conduit entrances should be carefully designed to preclude overflow of the trench onto the gallery floor. Contraction joint drains should discharge visibly into the drainage trench to permit monitoring of joint leakage. A float-operated alarm should be provided to indicate flooding of the lowest gallery.

(2) Oil storage and purifier rooms. Where oil storage or purifier rooms are provided with sprinkler systems, provide a chilling drain with a gravel pocket of sufficient capacity to handle the sprinkling system flow. When a CO_2 protected room is drained, the floor drain should be of nominal size and provided with a normally closed manual valve. Oil storage or purifier room drains should not drain directly to tailwater. They should first be routed to an oil separator facility.

(3) Battery room. Battery room floor and sink drains should be of acid resisting material, have a minimum 2 percent slope, no pockets or traps, and should discharge directly to the sump or tailrace.

(4) Miscellaneous area floor drains. Miscellaneous area floor drains should be provided in accordance with ASME A 31.1 and the Unified Plumbing Code. All floor areas below average peak-flow tailwater, and all other floor areas subject to flushing, leakage from, or periodic disassembly of water-filled equipment or piping should be drained. Any drains that come from a source that can add oil to the water should not drain directly to tailwater but should first be routed to an oil separator facility. The following areas are typical of most powerhouses, but the required areas of each powerhouse should be determined individually:

(a) Turbine rooms.

(b) Galleries.

(c) Water treatment room.

(d) Pump rooms.

(e) Locker rooms.

(f) Toilet rooms.

(g) Machine shop.

(h) Heating and ventilating equipment room.

(i) Gate repair pits.

(j) Gate and bulkhead storage pits.

(k) Pipe trenches.

(l) Elevator pits.

(m) Rigging rooms.

(n) Valve pits.

(5) Location of floor drains. Locating floor drains requires close coordination with structural and architectural requirements, but the following general considerations should apply.

(a) All areas where leakage, rainwater, water from disassembly, flushing, etc., is normally expected should have floors with continuous slope to the drain location. Examples of these areas are around pumps, strainers, janitor closets, outside decks, shower rooms, unloading areas, and drainage galleries.

(b) In other areas with unfinished level floors, it is desirable to locate drains in the center of a 910-1,220-mm (36-48-in.) depressed area to assist in directing water to the drain.

(c) In finished areas (terrazzo, tile) where slope or a depressed area can not be obtained, the drain location and elevation should be determined by the architect.

d. Equipment wastewater drainage.

(1) Gravity wastewater. The following equipment wastewater is normally drained to the sump through the drainage system piping:

(a) Pump gland drainage.

(b) Strainer drains.

(c) Condensate.

(d) Air compressor cooling water.

(e) Turbine head cover leakage.

(f) Heat exchanger.

(g) Turbine pit liner drainage.

Drainage should be collected and piped to the floor drains, sealed connections, or sight funnels. Open flows running horizontally across floors or drain lines should be avoided. Francis-type turbines are normally drained by gravity, and drainage from propeller turbines is normally pumped out of the turbine pits with pumps furnished by the turbine manufacturer. Capacity of gravity drain pipes may be estimated from Appendix B, paragraph B-6, "Capacity of Cast Iron Drain Lines."

(2) Pressure wastewater.

(a) Wastewater from generator air coolers and bearing coolers are normally piped directly to the tailrace. Some powerhouses also require pressure drains for transformer cooling water and air conditioning cooling water.

(b) The point of discharge for pressure drains requires careful consideration as several factors are involved. These include the following:

- Tailwater fluctuations.
- Available head (where the source is pool water).
- Pumping costs.
- Pressure conditions in coils and other equipment.
- Icing conditions.
- Requirement for flap valves or other protective shutoff valves.
- Line and valve maintenance.
- Esthetics (visibility of discharge).
- Fish passage channels.

An optimum discharge location would be above maximum tailwater for safety reasons. Where this is not practicable, a location above normal operating tailwater and the provision of a readily accessible shutoff valve at the point where the line becomes exposed in the powerhouse are preferred. A vented loop to prevent backflow from tailwater is satisfactory, but space requirements and the additional piping can make this provision impractical.

(c) Pressure discharge lines should be designed for maximum obtainable pressure conditions, and if an isolating valve is used, the effect of an inadvertent closure should be considered. Flap valves located below minimum tailwater are unsatisfactory because of inaccessibility for inspection and maintenance.

e. Drainage piping.

(1) General. Refer to Chapter 17 for general piping considerations.

(2) Embedded detail requirements.

(a) Embedding piping should be cast iron soil pipe.

(b) Horizontal turns should be long sweep.

(c) Vertical turns may be quarter bend.

(d) Minimum line size is 76 mm (3 in.).

(e) Slope in horizontal lines is preferably 2 percent and a minimum of 1 percent.

(f) Routing should be generally parallel with building lines to minimize interference with reinforcing steel and other embedded material.

(g) Lines crossing contraction joints require provision for flexibility. See detail in Appendix B, paragraph B-6.

(h) Lines more than one-third the thickness of wall or slab should not be embedded.

(3) Backflow valves. Drains in lower powerhouse areas may be fitted with backflow valves to minimize flooding under adverse conditions. However, such devices are not considered as positive protection against backflow in system design.

f. Drainage sump. The provisions noted in paragraph 11-2*b*(5) are applicable to drainage sumps. The drainage sump or joint unwatering-drainage sump should be located low enough to provide gravity flow from all drained areas under all dry powerhouse design tailwater conditions and up to the float-operated alarm, sump water elevation. Deviations from this requirement can occur in the case of certain low-drainage galleries deemed noncritical for short-term drainage interruptions. However, such applications should be discussed with review offices before proceeding with design.

g. Drainage pumps. Drainage pumps, whether separate or as combined drainage-unwatering pumps, should meet the provisions of paragraph 11-2*b*(6).

h. Drainage pump discharge. Refer to paragraph 11-2*b*(7) and Chapter 17 for pump discharge requirements.

i. Drainage sump overflow. The drainage sump should be provided with an overflow to the unwatering sump where separate drainage and unwatering sumps are provided. The overflow should be located slightly above the high water-level alarm elevation and should be provided with a flap valve to prevent flow from the unwatering sump to the drainage sump. The flap valve should be reasonably accessible for maintenance. It should be sized to bypass the drainage sump inflow capacity or unwatering pumps combined capacity to permit maximum utility in the event of an accident or flooding in the powerhouse.

j. Safety pool. Some projects with separate sumps provide for a "safety pool" of water in the draft tube when work is being done on the turbine runners. This is usually accomplished by allowing the unwatering sump water level to rise and overflow into the drainage sump through a valved opening. Thus, a valved opening between sumps is required. Drainage pump capacity has to handle the increased flows from all leakage into the unwatering sump.

k. Estimating drainage leakage. Leakage through contraction joints and cracks in floors and walls is usually the major uncertainty in estimating total drainage facility requirements. Where the powerhouse is a structure separate from the dam, 0.2 L/s per meter (1 gpm per foot) of powerhouse length is sometimes used. This tends to increase appreciably when the powerhouse is integral with the dam. Drainage to the powerhouse from a separate intake structure frequently is routed to the powerhouse drainage sump, and this is subject to the same uncertainty as the powerhouse leakage itself. The most reliable estimate is one based on an existing powerhouse of comparable size, configuration, and head conditions. Information on existing designs and operational experience is readily obtainable from district offices and through review offices.

l. External drainage. For some projects, it is expedient to route some of the drainage from the dam or other project facilities to the powerhouse drainage system. Such drainage should be limited to minor flows totalling not more than 10 percent of the estimated powerhouse drainage since any significant addition to potential flooding of the powerhouse should be avoided. Estimated drainage from such sources are subject to many variables, and it is a responsibility of the powerhouse designer to verify the estimates.

m. Transformer vault drains. Drains from areas in which oil-filled transformers are located should be discharged to draft tube gate slots when the water above the draft tube exit is confined to a holding pond, or to a similar method of storing spilled oil for later pumpout and disposal.

11-4. Equalizing (Filling)

a. General. A number of methods have been employed for equalizing at existing projects, but two preferred methods are described. Other methods involving equalizing headers or crossover connections are satisfactory in operation but introduce additional piping and valves along with increased flooding hazards in event of failure.

b. Low head projects. Low head projects up to about 38m (125 ft) usually have one or more intake gates and a set of draft tube bulkheads or stoplogs. Equalizing on these projects can be accomplished by opening the spiral case drain, cracking the intake gates, and filling the draft tube to tailwater then lowering the gates. After removing the bulkheads or stoplogs and closing the spiral case drain, the intake gates are again cracked open, and the spiral case and intake allowed to fill and equalized to pool head. The entire operation takes place with the wicket gates closed. No additional piping or valves are provided.

c. High head projects. Higher head projects provided with a penstock valve have a bypass valve for equalizing pressure across the penstock valve. Equalizing on these projects can be accomplished by filling to tailwater through valves provided in the draft tube bulkhead or stoplogs, removal of the bulkhead or stoplogs and filling, and equalizing the spiral case through the penstock valve bypass. The entire operation takes place with the wicket gates and spiral case drain closed. Additional equipment involved consists of one or more tag-line operated valves in a draft tube stop log or bulkhead. The tag-line operated valves should be a balanced type of valve to permit convenient tag-line operation in both directions and should be located near the top of the bulkhead or stoplog. Valve sizes should be consistent with the unwatering time noted in paragraph 11-2*b*(2). When upstream intake gate seals are used, cracking the gates to fill the penstocks should be avoided because of the possibility of gate catapulting during filling. For more information, see the April 1977 WES publication TRH-77-8. This publication can be purchased from the National Technical Information Center (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 as report AD A043 876. Costs of hard copies or microfiche copies of such reports are available from the NTIS on request.

11-5. Venting

When a penstock valve is utilized, the spiral case requires an air and vacuum relief valve to permit filling and unwatering. This valve and line should be sized to prevent less than one-half atmospheric pressure developing in the spiral case and should open to release air under pool pressure. The takeoff should be from the top of the casing or spiral case extension, and the vent line should be provided with a cutoff valve located as close to point of takeoff as practicable. Termination should be in a screened opening, above maximum tailwater, and clear of personnel areas.